FIRE

Project title: Dynamics of Climate, Fire, and Land Use Change in the Greater Yellowstone Ecosystem

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Objective: The history and future of fire as a disturbance process in forests of the western United States represents an intersection of two of the most pressing questions in ecosystem management. At local and regional scales, it is widely recognized that fire exclusion in fire-prone ecosystems during the 20th century has caused changes in forest structure and composition. These changes, in turn, are thought to be responsible for increasing the risk of widespread wildfire and outbreaks of pests and diseases (Sampson et al. 1994; Veblen et al. in press). In order to manage forest ecosystems, we must address the following question: How significantly has fire exclusion changed the fire regime during the present century and what are the impacts of that change on forest structure and composition?

At sub-continental scales, fire exclusion during the 20th century is seen as a primary driver of carbon accumulation in terrestrial ecosystems. The net flux of carbon attributable to historical land management within the western United States is significant (Houghton et al. 1999). Quantifying current and future status of these carbon pools is a critical component of the effort to develop a firm scientific base on which to negotiate, and potentially implement, the Kyoto Protocol (ref. to USGCRP). In order to move towards an era of carbon management, we must address the following question: How have past and current fire management policies altered carbon pools and what role might western forests play in an overall carbon management strategy for the future?

The ultimate goal of my research is to contribute to a sound scientific basis for managing fire at landscape as well as global scales. Towards this end, I am developing a research program that uses dendrochronological techniques to quantify the interactions of climate, fire and land-use as they structure forest composition, structure, and productivity within the Greater Yellowstone Ecosystem (GYE) over the last 300 to 1,000 years. To relate this goal with broader issues of global climate change, I collaborate with others in developing an integrated research program to address questions of the role of mountain regions, and specifically forests, in global change (e.g., coordinating committee of International Geosphere Biosphere Projects Global Change and Mountain Regions). I have a long history of research on climate and forest dynamics at time scales of seasons to millennia. I have obtained funding to continue research on fire history because 1) in general, disturbance is a critical mediator of the interaction of climate and ecosystem processes, and 2) specifically, fire is an important, but poorly understood, process in lower elevation forests of the GYE (Despain 1990; Meagher and Houston 1998).

Findings: The status of this project is ongoing, but preliminary results indicate the hypotheses presented in the objectives section are valid. Initial findings were presented at the Ecological Society of America's annual meeting in Madison, WI, August 4–8, 2001.

Abstract from that conference follows: Climate determinants of fire regime in the Greater Yellowstone Ecosystem (Jeremy S. Littell and Lisa J. Graumlich). Several decades of research describing pre-settlement fire regimes in western North American forests have demonstrated that fire, or its absence, is a strong determinant of ecological structure. A fundamental challenge in restoring fire in the West is to rely less on whether we have exceeded the natural range of forest structural variability and more on whether the structures we observe are compatible with fire regimes conditioned by current climate and future trends. Fire history research in the Greater Yellowstone Ecosystem has largely focused on describing fire-return intervals prior to European settlement. Very little research has attempted to link biophysical drivers and fire regimes in lower elevation (<2,500m) forests. Using dendrochronology to date fire scars and stand ages, we assembled fire histories for Douglas-fir (*Pseudotsuga menziesii*) forests and related these fire regimes to past climate. Over the last 500 years, low elevation forests had relatively high fire frequency (20–50 years) and fires tended toward lower intensity, non-stand replacing fires. Moreover, the frequency of these fires is related to regional climate anomalies. Thus, a century of fire suppression has had a far more dramatic effect on the structure of lower-elevation forests than on subalpine forests. Successful efforts to restore ecosystem structure and process must meld concepts related to natural range of variability with biophysical (i.e., climate) and social (i.e., land use) constraints.

I will be further analyzing the data sampled during the 2001 field season through the spring of 2002.

Project title: Postglacial Fire History and its Relation to Long-term Vegetational Changes in Yellowstone National Park

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Objective: The objective of this project is to study the climate, fire, and vegetation history of Yellowstone National Park. A network of pollen and plant macrofossil records from lakes and wetlands, spanning the last 14,000 years, has been examined from different environmental settings within the park. These data are used to reconstruct past changes in vegetation and climate. Information on past fire frequency is obtained from an analysis of particulate charcoal and lithologic variations in lake-sediment cores. The fire records are interpreted based on a study of modern charcoal deposition into lake sediments and a comparison of charcoal and dendrochronological records for the last 750 years. In 2001, the primary objective was to obtain sediment cores from Crevice Lake in northern Yellowstone Park. Crevice Lake has annually laminated sediments and thus offers the opportunity to reconstruct past variations in fire, climate, vegetation, and limnology with annual precision. The Crevice Lake project involves scientists from the University of Oregon, University of Nebraska, and U.S. Geological Survey.

Findings: Sediment cores from Crevice Lake were collected from the ice surface in February. A one-week fieldwork required helicopter and logistical support from Yellowstone Center for Resources and the Fire Cache. Sediment cores, ca. 5 to 6 m in length, were taken from three locations at water Departmenths of 27.5 m. The lithology consisted of laminated gyttja, with layers of marl and coarse sand. A volcanic ash, attributed to the eruption of Mount Mazama in southwestern Oregon, was present at 2.92 cm Departmenth. The bottom sediments consisted of gravels and clays, presumably of late-glacial age. Six radiocarbon dates on plant macrofossils were submitted for age determinations, and a date of 11,426 cal yr B.P. was obtained at 4.92 m Departmenth. An age-Departmenth model based on these dates suggests that each 1-2 mm-thick lamination represents annual deposition or varves. Our next step is to develop a varve chronology for the entire record, based on counting the annual laminations and comparing it with the radiocarbon chronology. This part of the research is underway at the University of Nebraska. In summer 2002, all collaborators will meet in Nebraska to sample the cores for pollen, charcoal, diatom, lithologic, geochemical, and isotopic analyses. The fire reconstruction will be part of the dissertation of Mitch Power at University of Oregon, and Whitlock will undertake the pollen analysis.

Analysis of modern sediments in lakes with watersheds that were burned in 1988 continued in 2001. This process-based study provides information necessary to interpret the charcoal record in sediment cores by examining the deposition of charcoal into lakes following a fire event. The study is one of four process-based charcoal studies in the world, and the results have been widely used by fire researchers. The samples are being evaluated in light of previous results (Whitlock and Millspaugh, 1996; Whitlock et al., 1997) and are discussed in two manuscripts that describe charcoal depositional processes (Whitlock and Anderson, in press; Whitlock and Larsen 2002).

Other accomplishments of note are publication of a paper describing the paleoecologic record of plant invasions in Yellowstone National Park in Western North American Naturalist (Whitlock and Millspaugh, 2001); acceptance of two chapters on charcoal methodology (Whitlock and Larsen, 2002; Whitlock and Anderson, in press). Results of this project are also featured in books on the Yellowstone fires (Millspaugh and Whitlock, in press) and Rocky Mountain ecosystems (Whitlock et al., in press).

Project title: The Status of Whitebark Pine Regeneration in the Greater Yellowstone Area Following the 1988 Fires: Burned vs. Unburned Forests and Mesic vs. Xeric Conditions; Assessment of Blister Rust Infection in Seedlings

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Objective: Whitebark pine *(Pinus albicaulis)* is a subalpine conifer that is linked to the viability of the grizzly bear population in the Greater Yellowstone. The pine is threatened by white pine blister rust, an introduced disease that has decimated populations in the northern Rocky Mountains and is a growing problem in the Greater Yellowstone Area. In 1990, D. F. Tomback established 275 permanent plots in the Greater Yellowstone Area to monitor the progress of whitebark pine regeneration after the 1988 Yellowstone fires. Of these plots, 125 are in Yellowstone National Park, representing three "treatments:" stand-replacing burn, dry; stand-replacing burn, moist; and mixed severity burn, moist. In the Park, "moist" treatments had northerly exposures, and the "dry" treatment a westerly exposure. Plots were monitored for six years, with the first whitebark pine seedlings appearing in 1991 on all treatments. The study plots were revisited in 2001 to determine the 1) current regeneration densities of whitebark pine with respect to treatment, 2) cover and composition of understory plants, 3) survival of individual seedlings alive in 1995, 4) differences in water availability for soil subsurface among treatments, 5) differences in water use efficiencies of whitebark pine seedlings, 6) blister rust infection rate of seedlings in plots, and 7) prevalence of blister rust in unburned whitebark pine stands closest to each treatment. Data were gathered from the third week in June through the first week in August. Meteorological stations, including soil moisture probes and data loggers were set up in the burned treatments, and foliage was sampled from seedlings off plot for studies of photosynthetic efficiency. Plots were carefully surveyed by a team of four people, and nearby stands were surveyed for blister rust prevalence by teams of two to five people. Most work on soil moisture measurements and blister rust surveys is scheduled for summer of 2002.

Findings: The data gathered are currently being entered in several different databases for extensive statistical analysis. Final results are not anticipated for at least a year. Some general results of the study are as follows: Whitebark pine regeneration densities in all treatments inside and outside the Park are increasing over time since the 1988 fires. The greatest regeneration densities of all conifers, and particularly whitebark pine, occur on the stand-replacing burn, moist treatment in the vicinity of Dunraven Pass. In 2001, the number of newly emerged whitebark pine seedlings that occurred on this treatment was unprecedented for this study. Regeneration densities of associated conifers, subalpine fir, Engelmann spruce, lodgepole pine, Douglas fir, were also very high for this treatment. Our preliminary impression is that the dry treatment on Mt. Washburn supports comparatively low densities of whitebark pine with respect to all seven treatments in this study (three in the Park). Understory plant diversity and cover has increased through time, including the presence of several exotic grasses. Studies of soil moisture patterns and seedling water use efficiency are still in progress. No seedlings were obviously infected with white pine blister rust; and the few whitebark pine stands inspected in summer 2001 adjacent to the Park treatments on Mt. Washburn are still free of obvious blister rust symptoms. However, the stands on Henderson Mountain, just northeast of the east Park boundary, are infected with blister rust. At this time there is little to no kill or mortality in these stands, but multiple cankers and some branch flagging are apparent. For the Mt. Washburn stands, it is only a matter of time before the blister rust infection reaches this area. To date, it appears that natural regeneration is effectively restocking the 1988 burned areas in the Park, but with pronounced differences between moist and dry sites.

Project title: Post-Burn Resource Selection, Physiological Condition, and Demographic Performance of Elk

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Objective: The primary objective of this research is to evaluate the consequences of the 1988 fires on elk resource selection. Selection is being quantified for populations and individuals at multiple scales ranging from selection of patches within the landscape mosaic to selection of forages and plant parts within patches. The physiological and demographic consequences of observed resource selection strategies are being assessed through noninvasive urinary and fecal assays, and telemetry. Secondary objectives include basic research on forage plant chemical compositions, plant-animal interactions and applied research to develop practical and rigorous management tools for population monitoring (aerial surveys, fecal steroid pregnancy assays, and snow-urine condition indices).

Findings: We have been successful in developing, testing, and applying a suite of research tools that is significantly enhancing our ability to address questions of animal resource selection and the physiological and demographic consequences of selection patterns. We have completed our tenth field season of data collection and maintain an instrumented population of 30–40 cow elk. Most publications to date have focused on techniques including population estimation, pregnancy assessment, and nutritional indices. This year we completed a manuscript analyzing the demographic data collected during the first seven years of research, which is currently being considered by Canadian Journal of Zoology and have a second manuscript on geochemical trophic cascades accepted in the journal Ecosystems. Adult survival and reproduction is near the biological maximum for the species, but recruitment is highly variable, being strongly influenced by environmental variation, primarily winter severity. Despite this variable recruitment, extensive Monte Carlo simulations indicate that the population is relatively stable and is being regulated at approximately 600–800 animals. We have generated a database of greater than 10,000 animal locations and are exploring a variety of analytical tools for the analysis of these data. We have continued to acquire and develop GIS data sets of landscape features for integration with all spatially-explicit data collected on this study. We are currently developing spatially-explicit snowpack models in collaboration with NASA scientists to enhance our analyses of elk resource selection.

Project title: Recolonization of Lichens Since the 1988 Fires

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Objective: The objectives of the study in 2001 were to examine substrates burned in 1988 for recolonization by lichens, and to measure largest colonies or thalli for estimates of growth rates. The working hypothesis was that moister spruce and Douglas fir forests would have more substrates recolonized than other sites, more species would be present and the thalli would be larger.

Findings: We visited 30 sites burned in 1988: ten lodgepole pine sites, five whitebark pine, five Douglas fir, five spruce and five grassland/meadow. A site was a discrete area within a burned stand. Some stands were in the center of extensively burned sites, and others were more mosaic with live standing trees adjacent to the burned area investigated. The latter was more common in spruce and Douglas fir sites. Distance to unburned trees was estimated. Lichens, mosses and small fungi were all present on charred logs so all these organisms were recorded. When the species was not readily identified in the field, the sample was collected for laboratory identification.

The circumference and entire length of ten burned, downed logs at each site were thoroughly examined for recolonizing species. When present, snags were also examined, as were soil and rocks. The largest colony or thallus for each lichen species was measured in order to get an estimate of maximum colonization and growth rate. Burned rock and soil substrates are more ambiguous than burned logs and snags.

Preliminary results support part of the original hypothesis. About 80% of the logs in spruce sites were being recolonized with lichens and/or mosses, while logs in other forest sites averaged closer to 40–50%. The percentage of logs with no new growth of lichens, moss or fungi was higher in lodgepole pine, whitebark pine, and Douglas fir sites (ca. 21%, 32% and 32%, respectively) than in spruce sites (ca. 5%). A slightly higher percentage of logs had more new lichen growth than moss, except in lodgepole pine sites where slightly more logs had mosses than lichens. However, on logs with new growth, the moss growth was substantially more extensive than the lichen growth. This was especially true for logs lying on the ground, where mosses appeared to grow from shaded moist soil under the log up onto the log, particularly in cracks. Most of the growth of mosses and lichens was on shaded parts of logs close to the ground. The fungi tended to be anywhere on the logs.

Dominant species identified so far on logs and snags are *Cladonia coniocraea*, *C. fimbriata*, *Letharia vulpine*, *Bryoria fuscescens*, *Usnea substerilis*, *Xanthoria fulva* and species of *Physica*, all sorediate species common in Yellowstone forests. *Peltigera rufescens* and *P. didactyla* were common on burned soils. Primary mosses on logs were *Ceratodon purpureus* and species of *Bryum*. P*olytrichum piliferum* and *P. juniperinum* were on burned soils. Work is still in progress on identification of all moss and fungus species, and on data analysis for soils and rocks.

Project title: Fire: A Force for Change and Regeneration in a Natural Ecosystem

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Objective: To monitor growth rates and reproduction of vegetation, particularly lodgepole pine, at sites affected by various fire intensities from the fires of 1988 and to provide a long-term photographic record of vegetation change in those sites.

Findings: This year was year 12 of the study. Growth rates of lodgepole pine saplings varied from 34 cm/yr to 46 cm/yr. Lowest increases occurred at the Frying Pan Springs site. The highest increases occurred at the Norris-Canyon blowdown area and the site one mile S of Norris Junction. Reproduction (male and female cones) is now occurring at all study sites, and is especially vigorous at sites affected by severe fire intensity. The tallest post-fire saplings, south of Norris Junction, are 4.75 meters (15.58 ft) tall. The sites north of Madison Junction, near Tuff Cliff, could not be sampled in 2001 due to heavy road construction equipment operating in the area.